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June, 1980

ENERGY RESEARCH PROGRAM

MINING RESEARCH LABORATORIES

REPORT ERP/MRL 80-65 (TR)

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SUMMARY AND CONCLUSION

Light diesel fuel (SG = 0.805) was employed in a dynamometer-coupled Deutz F6L 912W indirect injection diesel engine, in both a cold and a hot condition, in order to determine the effects of fuel temperature on fuel consumption and on the concentrations of CO and carbon particulate matter in the exhaust gases generated at near maximum load/speed operating conditions.

Three test runs on three different days indicated that, for a given engine torque and speed, and fuel temperature increases from 75°F/24°C to 180°F/83°C:

- (1) no significant, variation in fuel flow rate was observed and,
- (2) no significant overall variation in the generation of particulate matter was observed, and
- (3) a minor 12% reduction in the generation of CO was observed. (i.e. 210 ppm to 185 ppm approximately).

Consequently, it does not appear that this emissions reduction strategy is useful in underground applications where IDI engines are widely used.

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INTRODUCTION

A Toronto firm has been marketing an 'energy-saving' device which is essentially a heat exchanger which takes heat from the engine coolant and transfers it to the fuel oil, heating it from ambient temperatures to about 180°F/82°C. Summaries of several investigations were presented to the CEAL staff which suggested that use of this strategy would result in improved fuel economy and reduced pollutants in the emissions.

However, the data presented did not definitively establish that the fuel rate and pollutant levels at the different fuel temperatures were pertinent to the same load/speed operating condition of the engine. Because this difficulty could easily be overcome using the CEAL facility and because such a simple strategy could be readily demonstrated and would be valuable if proven effective, it was decided to see if claimed benefits for hot diesel oil were actually forthcoming.

APPARATUS AND METHOD

The Deutz F6L 912W is an air-cooled, six cylinder, in-line configuration, indirect injection diesel engine, which is particularly suited to underground applications because of low levels of toxic pollutants in the exhaust.

The standard laboratory fuel system was modified so that ordinary fuel (never heated and called 'cold fuel'), could be used in the normal manner. Added to the system in parallel, were two other fuel reservoirs: one for cold fuel that had been heated once to 180°F/82°C and subsequently cooled before use (called 'cold hot' fuel) and one for hot fuel heated to the same temperature once and used for the hot fuel tests (called 'hot hot' fuel).

The volumetric flow rates of the 'cold' fuel and the 'cold hot' fuel were measured using the standard laboratory technique i.e. measuring the time required for the engine to consume the precise volume of the fuel contained in the bulb of the measuring apparatus. The 'hot hot' fuel was contained in a heated drum and the rate was measured using a weight scale and timing the test period over which the weight loss of the fuel drum took place.

The temperature of the 8 gallon 'hot hot' fuel tank was controlled using an external Haake controller which circulated hot water just under the boiling point to a coil in the 8 gallon drum. This setup required an approximate 4 hour oil warmup period.

The torque, speed, fuel and air rate variables were measured among others, and O_2 , CO_2 , and CO plus particulate matter were measured. These major variables and all others that were measured are listed in Table 1 along with the computed values necessary to make appropriate comparisons.

DISCUSSION

Analyses of both cold fuel and fuel heated once to 180°F were made as follows:

fuel	cold	heated once
Carbon (% wt.)	86.30	86.37
hydrogen (% wt.)	13.60	13.62
sulphur (% wt.)	0.13	0.14
initial boiling point (°F)	328	328
5% recovery temp (°F)	347	346
10% recovery temp (°F)	358	356

These analyses are virtually identical so that analysis variations between hot and cold fuels did not contribute to the results discussed below.

During preliminary runs it was determined that thermal expansion due to heating the oil reduced the maximum fuel weight throughput of the fuel pump thus reducing the maximum load available at full speed. Consequently, it was decided that the tests to compare fuel rate and emissions should be performed at identical torques and speeds which the engine was readily capable of producing, i.e. 264 Nm (195 lb ft) and 2300 rpm. However, this load likewise proved marginal and the final two tests were carried out at a torque of 258 Nm (190 lb ft). Even this load proved marginal in run 3 because, presumably, the intake air was hotter reducing the cylinder charge a little.

A glance at Table 1 shows that the measured fuel/air ratios and those inferred from combustion calculations using O_2 concentrations, correspond within an average differential of 1.9%. Because of this acceptable correspondence, and because two test fuel measurements were not made, it was decided to use the inferred fuel/air ratio and the measured air rate to compute the fuel rate used in the calculation of the brake specific fuel consumption values used in Table 1.

When this is done it is clear that the fuel rates do not vary significantly among tests for the same operating conditions, and even when the torque variation was slight (run 3 test 3) the brake specific fuel consumption does not vary significantly. This indicates that this strategy does not result in a fuel rate reduction for this IDI engine near maximum load/speed operating conditions.

Figure 1 shows the particulate concentration variations with fuel temperature for 3 separate runs and the average for all three runs to indicate the general trend. This data suggests that no significant particulate concentration trend, up or down, results from fuel temperature comparisons made at the same load/speed operating conditions.

Examination of the CO results does suggest that the hot fuel tends to reduce the CO concentration marginally, say 12%. From an underground environmental impact point of view this is not significant.

In the face of these results one finds difficulty in explaining why other less well documented studies suggest reduced fuel consumption for heated fuel. The heat added to the combustion system is only 0.27% of the fuel input - not significant and not measurable by normal fuel consumption determination means.

Heating fuel from 75°F to 180°F increases the specific volume of the fuel (the volume per unit weight) an estimated 5%. Also, this temperature increase reduces the viscosity of the oil about 7 times thus increasing the pump piston by-pass fuel flow significantly, thus further reducing the fuel throughput to the engine, but by an unknown amount. These two considerations suggest that the maximum fuel flow rate for an engine mounted for testing in a truck or a tractor for example, would be reduced in excess of 5%. This effect explains why these CEAL tests described here were not performed at full output torque on cold fuel. One set of data supplied to CEAL also confirms this effect (University of Wisconsin tests on a farm diesel tractor

May 1979); i.e. horsepower output with no fuel heating effect was 92 bhp, compared to the output with the heater of 88 bhp. This represents a 4.3% power reduction as suggested by the volumetric change in the oil due to temperature increase; the corresponding 8.9% reduction in fuel consumption indicated by the same farm tractor tests, more than offsets this load reduction however.

It is assumed that all prior test data on this device is applicable to direct injection diesel engines. The failure of these tests to indicate fuel rate improvements may be a function of the indirect injection combustion systems.

Table 1 - Effect of Heated Diesel Fuel on Particulate Generation and Fuel Consumption for a Deutz F6L 912W Engine #1

Run No.	Fuel type	Engine speed rpm	Engine torque lb ft (Nm)	power bhp (kw)	msrd fuel flow lb/hr (kg/hr)	msrd air flow lb/hr (kg/hr)	msrd f/a	exhaust CO2 (\$)	exhaust O2 (\$)	inferred f/a #2	exhaust temp. °F (°C)	air inlet temp. °F (°C)	fuel temp. °F (°C)	exhaust CO ppm (ppm)	exhaust particulate mg/m ³ (kg/kw.hr)	BSFC #2 lb/bhp.hr (kg/kw.hr)
1	never-heated	2300 (2300)	195 (264)	85.4 (63.5)	34.6 (15.7)	766 (347)	0.0452 (0.0452)	9.40 (9.40)	7.60 (7.60)	0.0436 (0.0436)	900 (482)	75 (24)	75 (24)	205 (205)	52 (52)	0.391 (0.238)
2	cooled hot fuel	2300 (2300)	195 (264)	85.4 (63.5)	-	764 (346)	-	9.35 (9.35)	7.81 (7.81)	0.0430 (0.0430)	900 (482)	76 (24)	91 (33)	191 (191)	48 (48)	0.385 (0.234)
3	hot fuel	2300 (2300)	195 (264)	85.4 (63.5)	33.8 (15.3)	768 (348)	0.0440 (0.0440)	9.28 (9.28)	7.83 (7.83)	0.0429 (0.0429)	892 (478)	75 (24)	183 (84)	187 (187)	42 (42)	0.386 (0.235)
2	cooled hot fuel	2300 (2300)	190 (258)	83.2 (61.8)	33.7 (15.3)	770 (349)	0.0438 (0.0438)	9.22 (9.22)	8.00 (8.00)	0.0423 (0.0423)	855 (457)	74 (23)	73 (23)	215 (215)	30 (30)	0.391 (0.238)
2	hot fuel	2300 (2300)	190 (258)	83.2 (61.8)	-	770 (349)	-	9.23 (9.23)	8.00 (8.00)	0.0423 (0.0423)	855 (457)	74 (23)	181 (83)	190 (190)	31 (31)	0.391 (0.238)
3	never-heated	2300 (2300)	190 (258)	83.2 (61.8)	33.7 (15.3)	767 (348)	0.0439 (0.0439)	9.59 (9.59)	7.77 (7.77)	0.0431 (0.0431)	905 (485)	85 (29)	71 (22)	190 (190)	37 (37)	0.397 (0.241)
2	cooled hot fuel	2300 (2300)	190 (258)	83.2 (61.8)	33.7 (15.3)	770 (349)	0.438 (0.0438)	9.58 (9.58)	7.75 (7.75)	0.0432 (0.0432)	910 (488)	88 (31)	71 (22)	183 (183)	31 (31)	0.400 (0.243)
3	hot fuel	2295 (2295)	188 (255)	82.2 (61.1)	32.5 (14.7)	767 (348)	0.0424 (0.0424)	9.53 (9.53)	7.83 (7.83)	0.0429 (0.0429)	897 (481)	88 (31)	182 (83)	175 (175)	37 (37)	0.400 (0.243)

#1 6 cylinder, in-line, air-cooled, indirect injection diesel, timing: 26 3/4° BTDC, maximum torque/speed = 205 ft lbs/2300 rpm (278 Nm/2300 rpm)

#2 inferred f/a ratio based on O₂ concentration, and, fuel rate for the brake specific fuel consumption in lb/bhp.hr (kg/kw.hr) likewise based on the fuel/air ratios derived from O₂ concentration.

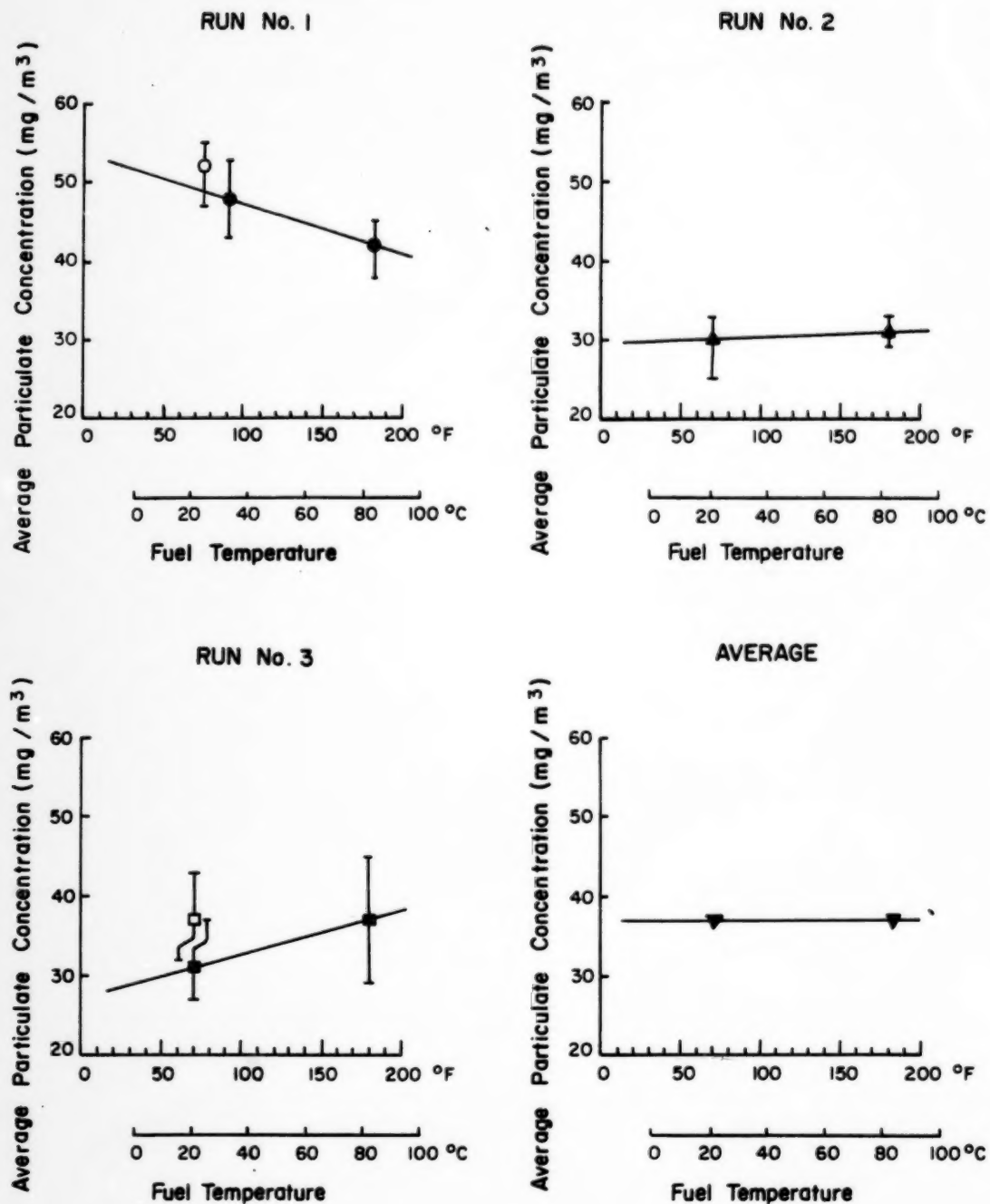


Fig. 1 Effect of Heated Diesel Fuel On Particulate Generation For a Deutz F6L 912W Engine

